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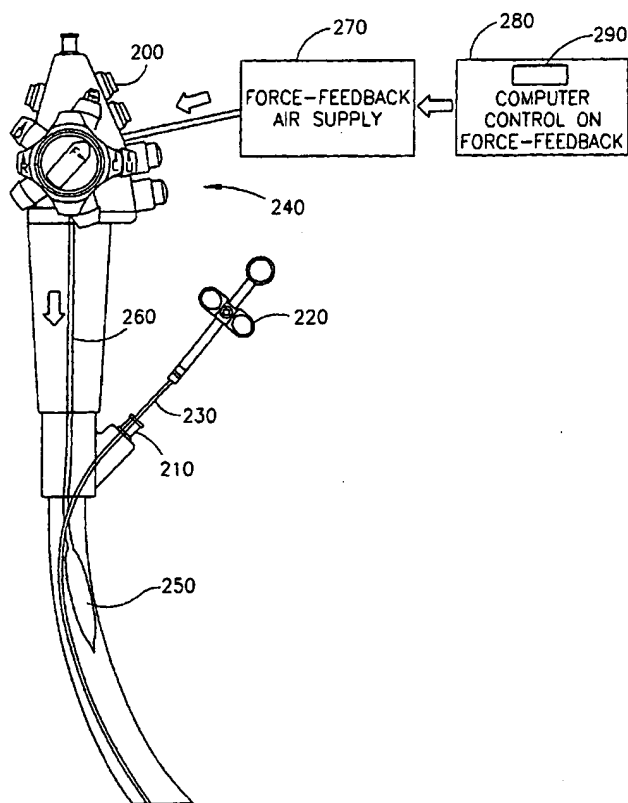
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(54) Title: **TOOLS FOR ENDOSCOPIC TUTORIAL SYSTEM**

(57) Abstract: A tool for use with a system for simulating the minimally invasive medical procedure of endoscopy, particularly of flexible gastroendoscopy. The tools support the close simulation of the actual medical procedure of endoscopy by simulating medical instruments in the context of providing tactile and visual feedback as the simulated procedure is performed on the simulated patient.

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TOOLS FOR ENDOSCOPIC TUTORIAL SYSTEM

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to tools for teaching and training students in
5 medical procedures, and in particular to the use of such tools for training students in
the procedure of endoscopy, in which the tools are able to simulate force feedback
provided during the performance of the actual medical procedure on a living subject.

Endoscopy, and in particular flexible gastro-endoscopy, are examples of
minimally invasive medical procedures. Flexible gastro-endoscopy is an important
10 medical tool for both surgical and diagnostic procedures in the gastro-intestinal tract.
Essentially, gastro-endoscopy is performed by inserting an endoscope, which is a
flexible tube, into the gastro-intestinal tract, either through the mouth or the rectum of
the subject. The tube is manipulated by a trained physician through specialized
controls. The end of the tube which is inserted into the subject contains a camera and
15 one or more surgical tools, such as a clipper for removing tissue samples from the
gastro-intestinal tract. The physician must maneuver the tube according to images of
the gastro-intestinal tract received from the camera and displayed on a video screen.
The lack of direct visual feedback from the gastro-intestinal tract is one factor which
renders endoscopy a complex and difficult procedure to master. Such lack of feedback
20 also increases the difficulty of hand-eye coordination and correct manipulation of the
endoscopic device. Thus, flexible gastro-endoscopy is a difficult procedure to both
perform and to learn.

Currently, students are taught to perform flexible gastro-endoscopy according
to the traditional model for medical education, in which students observe and assist
25 more experienced physicians. Unfortunately, such observation alone cannot provide
the necessary training for such complicated medical procedures. Students may also
perform procedures on animals and human cadavers, neither of which replicates the
visual and tactile sensations of a live human patient. Thus, traditional medical training
is not adequate for modern technologically complex medical procedures.

30 In an attempt to provide more realistic medical training for such procedures,
simulation devices have been developed which attempt to replicate the tactile
sensations and/or visual feedback for these procedures, in order to provide improved
medical training without endangering human patients. An example of such a

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simulation device is disclosed in U.S. Patent No. 5,403,191, in which the disclosed device is a box containing simulated human organs. Various surgical laparoscopic procedures can be performed on the simulated organs. Visual feedback is provided by a system of mirrors. However, the system of both visual and tactile feedback is primitive in this device, and does not provide a true representation of the visual and tactile sensations which would accompany such surgical procedures in a human patient. Furthermore, the box itself is not a realistic representation of the three-dimensional structure of a human patient. Thus, the disclosed device is lacking in many important aspects and fails to meet the needs of a medical simulation device.

Attempts to provide a more realistic experience from a medical simulation devices are disclosed in PCT Patent Application Nos. WO 96/16389 and WO 95/02233. Both of these applications disclose a device for providing a simulation of the surgical procedure of laparoscopy. Both devices include a mannequin in the shape of a human torso, with various points at which simulated surgical instruments are placed. However, the devices are limited in that the positions of the simulated surgical instruments are predetermined, which is not a realistic scenario. Furthermore, the visual feedback is based upon a stream of video images taken from actual surgical procedures. However, such simple rendering of video images would result in inaccurate or unrealistic images as portions of the video data would need to be removed for greater processing speed. Alternatively, the video processing would consume such massive amounts of computational time and resources that the entire system would fail to respond in a realistic time period to the actions of the student. At the very minimum, a dedicated graphics workstation would be required, rather than a personal computer (PC). Thus, neither reference teaches or discloses adequate visual processing for real time visual feedback of the simulated medical procedure.

Similarly, U.S. Patent No. 4,907,973 discloses a device for simulating the medical procedure of flexible gastro-endoscopy. The disclosed device also suffers from the deficiencies of the above-referenced background art devices, in that the visual feedback system is based upon rendering of video data taken from actual endoscopic procedures. As noted previously, displaying such data would either require massive computational resources, or else would simply require too much time for a realistic visual feedback response. Thus, the disclosed device also suffers from the deficiencies of the background art.

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A truly useful and efficient medical simulation device for minimally invasive therapeutic procedures such as endoscopy would give real time, accurate and realistic visual feedback of the procedure, and would also give realistic tactile feedback, so that the visual and tactile systems would be accurately linked for the simulation as for an actual medical procedure. In addition, such a device would enable the student to manipulate tools which may be required during the performance of the actual medical procedure. Unfortunately, tools for operation with such a simulation device are not currently taught or provided by the background art, nor is the device itself taught or provided in the background art.

There is therefore a need for, and it would be useful to have, a method, a device and a system to simulate a minimally invasive medical procedure such as endoscopy, particularly with regard to the operation of tools which may be required during the performance of the actual medical procedure.

SUMMARY OF THE INVENTION

The present invention features tools for use with a system for simulating the minimally invasive medical procedure of endoscopy, particularly of flexible gastro-endoscopy. The tools support the close simulation of the actual medical procedure of endoscopy by simulating medical instruments in the context of providing tactile and visual feedback as the simulated procedure is performed on the simulated patient. In addition, the present invention features a specific mechanism for providing force feedback on the tools for a more realistic and accurate operation thereof, as well as methods for correctly calculating the forces which should be applied to the tools through such a force feedback mechanism.

The inventors of the present invention have previously overcome the deficiencies of the background art, by providing a general simulation system, method and device, for enabling students to practice the medical procedure through an accurate, realistic simulation thereof, as disclosed in published PCT Application No. WO 99/38141, filed on January 15, 1999 and incorporated by reference as if fully set forth herein. However, surprisingly the present inventors have found an improved, specific mechanism for the simulation of the operation of various tools during the medical procedure, which is described in the present application.

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According to the present invention, there is provided a simulated medical tool for manipulation in a simulated organ by a user, comprising: (a) a tool body; (b) a tool handle attached to the tool body for manipulation by the user; (c) a cable contained in the tool body; (d) a negative electrode attached to the cable; and (e) a positive
5 electrode adjacent to the cable, the positive electrode being in electrical contact with the negative electrode without physically contacting the cable, such that an electrical circuit is formed for providing potentiometric resistance on the cable.

According to another embodiment of the present invention, there is provided a system for simulating a medical procedure by a user, the system comprising: (a) a
10 simulated organ; (b) a simulated tool for entering into the simulated organ for performing the simulated medical procedure, the simulated tool comprising: (i) a tool body; (ii) a tool handle attached to the tool body for manipulation by the user; (iii) a cable contained in the tool body; (iv) a negative electrode attached to the cable; and (v)
15 a positive electrode adjacent to the cable, the positive electrode being in electrical contact with the negative electrode without physically contacting the cable, such that an electrical circuit is formed for providing potentiometric resistance on the cable, an amount of the resistance being proportional to a distance traveled by the cable; and (c) a visual display for providing visual feedback according to the distance traveled by the cable in the simulated organ.

20 According to yet another embodiment of the present invention, there is provided a simulated medical tool for manipulation in a simulated medical procedure by a user, comprising: (a) a tool body; (b) a tool handle attached to the tool body for manipulation by the user; (c) an air-based force generating system for generating a force against the tool body to provide force feedback to the user, the air-based force
25 generating system generating the force against the tool body according to air pressure to simulate the medical procedure.

The method of the present invention for preparing a model of the simulated organ, and for rendering the visual feedback of the simulated organ during the simulated medical procedure, can be described as a plurality of instructions being
30 performed by a data processor. As such, these instructions can be implemented in hardware, software or firmware, or a combination thereof. As software, the steps of the method of the present invention could be implemented in substantially any suitable

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programming language which could easily be selected by one of ordinary skill in the art, including but not limited to, C and C++.

Hereinafter, the term “simulated medical procedure” refers to the simulation of the medical procedure as performed through the system and method of the present invention. Hereinafter, the term “actual medical procedure” refers to the performance of the medical procedure on an actual, living human patient with an actual endoscope, such that the medical procedure is “real” rather than “simulated”. Hereinafter, the term “corresponding actual organ” refers to the “real” organ of a human being or other mammal which is being simulated by the simulated organ of the present invention.

Hereinafter, the term “endoscopy” includes, but is not limited to, the procedure of flexible gastro-endoscopy, as previously described, and medical diagnostic and surgical procedures in which an endoscope is inserted into the mouth or the rectum of the subject for manipulation within the gastro-intestinal tract of the subject. Hereinafter, the term “subject” refers to the human or lower mammal upon which the method and system of the present invention are performed or operated. Hereinafter, the term “student” refers to any human using the system of the present invention, being trained according to the present invention or being taught according to the present invention including, but not limited to, students attending medical school or a university, a medical doctor, a trained gastro-enterologist or other trained medical specialist.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, aspects and advantages will be better understood from the following detailed description of a preferred embodiment of the invention with reference to the drawings, wherein:

FIG. 1 is an exemplary illustration of the system for medical simulation according to the present invention;

FIG. 2 shows the visual processing and display system of Figure 1 in more detail;

FIGS. 3A and 3B are schematic block diagrams of the simulated biopsy device of the present invention;

FIG. 4 is a cut-away side view of a preferred embodiment of the simulated biopsy device of Figures 3A and 3B;

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FIGS. 5A-5D are detailed views of portions of the device of Figure 4; and
FIG. 6 is a schematic diagram of a cut-away view of an exemplary but
preferred implementation of the force feedback mechanism for the tools according to
the present invention.

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DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention features tools for use with a system for simulating the
minimally invasive medical procedure of endoscopy, particularly of flexible
gastro-endoscopy. The tools support the close simulation of the actual medical
10 procedure of endoscopy by simulating medical instruments in the context of providing
tactile and visual feedback as the simulated procedure is performed on the simulated
patient.

The tool of the present invention is described in the preferred exemplary
embodiment of a simulated biopsy device, although clearly other tools could also be
15 simulated. The present invention is able to provide physical and visual feedback
through the use of potentiometry, which involves an electrical current to generate
resistance on the simulated tool.

According to preferred embodiments of the present invention, potentiometric
resistance is provided on a flexible, moving object, such as the flexible cable of the
20 biopsy device, without attaching the entire electrical supply directly to the cable.
Instead, one electrode (shown below as the negative electrode) is attached directly to
the cable, while the other electrode (shown below as the positive electrode) is
attached indirectly, to a wire wrapped around the cable. Thus, both electrodes are
provided without directly attaching both to the flexible cable.

25 The present invention enables linear potentiometric resistance to be generated
on the flexible cable of the simulated biopsy device, which is important both for
accurately determining the resistance which is required, and for determining the
distance which has been traveled by the flexible cable. The traveled distance is
preferred for providing accurate visual feedback, in terms of the relative location of the
30 simulated biopsy device within the simulated gastro-intestinal tract and/or endoscope
of the present invention.

The principles and operation of the present invention may be better understood
with reference to the drawings and the accompanying description, it being understood

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that these drawings are given for illustrative purposes only and are not meant to be limiting. Furthermore, although the description below is directed toward the simulation of the colon, it should be noted that this is only for the purposes of clarity and is not meant to be limiting in any way.

5 Referring now to the drawings, Figure 1 depicts an exemplary, illustrative system for medical simulation for use with the tools according to the present invention. A system 10 includes a mannequin 12 representing the subject on which the procedure is to be performed, a simulated endoscope 14 and a computer 16 with a video monitor 18. A student 20 is shown interacting with system 10 by manipulating simulated
10 endoscope 14 within mannequin 12. Mannequin 12 includes a simulated organ into which simulated endoscope 14 is inserted. As student 20 manipulates simulated endoscope 14, tactile and visual feedback are determined according to the position of endoscope 14 within the simulated organ (not shown). The visual feedback are provided in the form of a display on video monitor 18. The necessary data calculations
15 are performed by computer 16, so that realistic tactile and visual feedback are provided to student 20.

As shown with regard to Figure 2, the system of Figure 1 provides a solution to a number of problems in the art of medical simulation, in particular for the simulation of the procedure of gastro-endoscopy. This procedure involves the visual
20 display of an interior portion of the gastrointestinal tract, such as the colon. The colon is a flexible body with a curved structure. The inner surface of the colon is generally deformable, as well as being specifically, locally deformable. All of these deformations in space must be calculated according to the mathematical model of the colon, and then rendered visually in real time in order to provide a realistic visual
25 feedback response for the user.

Figure 2 shows the visual processing and display system of Figure 1 in more detail. A visual processing and display system 40 includes screen display 22 for displaying the processed visual data. The visual data are constructed as follows. First, data are recorded from actual gastro-endoscopic procedures onto videotape, as shown
30 in a recording block 42. The data are preferably stored on Super-VHF videotape in order to obtain the highest quality representation of the visual images displayed on the screen during the actual endoscopic procedure, as shown in block 44. Next, at least a

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portion of the frames of the videotape, and preferably substantially all the frames, are abstracted individually by a frame-grabber 46 to form digitized images. Individual digitized images can then be selected for clarity and lack of artifacts such as reflections from the endoscopic apparatus itself. The images in the selected frames are then

5 preferably enhanced and added to a texture mapping database 48.

Preferably, two types of texture mapping are stored in the database. The first type of texture mapping is intended to enhance the realistic visual aspects of the images, for example by removing visual artifacts. The second type of texture mapping is intended to simulate the behavior of a live organ and a real endoscope, as

10 represented by block 50. During actual endoscopic procedures on a living human patient, the tissue of the colon moves somewhat, and the endoscope itself vibrates and wobbles. This movement is simulated visually by the addition of random animation of the images, and also by the addition of such effects as liquid flowing downward due to the influence of gravity. Such animation enhances the realistic nature of the visual

15 representation of the colon.

In order for the enhanced images to be correctly displayed, the images must correspond to the manipulation and location of the simulated endoscope within the simulated colon. In particular, the texture mapping of the images should correspond to the location of the endoscope within the colon. Such correspondence between the

20 location of the endoscope within the colon and the texture mapping is provided by a texture mapping engine 52. The texture mapping data is then readily accessed by the display portion of visual system 40, as shown by block 54.

However, as noted for previous background art devices, simply reproducing the selected enhanced frames in a massive video stream would quickly overwhelm the

25 computational resources and cause the visual display to become unsynchronized from the physical location of the simulated endoscope. Furthermore, such a video stream would not enable the correct display of images according to the movement of the endoscope, which preferably has six degrees of freedom. Thus, mere reproduction is not sufficient to ensure realistic images, even when mapped onto a three-dimensional

30 surface.

Preferably, visual processing and display system 40 includes a three-dimensional mathematical model of at least a portion of the gastro-intestinal tract

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56. For the purposes of discussion, model 56 is herein described as a three-dimensional model of the colon, it being understood that this is not meant to be limiting in any way. Model 56 preferably features a plurality of segments 58, more preferably many such segments 58.

5 As the simulated endoscope moves along the simulated colon, the location of the endoscope is given to a locator 60, described in further detail below. Locator 60 then instructs an object loader 62 to load the relevant segment 58 for access by visual system 40, as shown in block 54 and previously described. In the preferred embodiment shown, preferably three segments 58 are ready for access by object loader
10 62 at any given moment. The specific segment 58 in which the endoscope is currently located is preferably held in DRAM or RAM, in combination with the texture mapping described previously. The next segment 58 and the preceding segment 58 preferably are also stored in an easily accessible location, although not necessarily in RAM or DRAM.

15 Preferably, the display of each image from specific segment 58 into which the simulated endoscope has entered is optimized by a segment optimizer 64. Segment optimizer 64 receives information from locator 60, as well as the series of images obtained from overlaying the texture mapping onto the relevant segment 58, and then feeds each specific image to a display manager 66 for display on screen display 22.

20 In addition, display manager 66 is assisted by a real-time viewer 68, preferably implemented in Direct 3D™ (Microsoft Corp., USA). Real-time viewer 68 provides the necessary software support to communicate with a graphics card 70 for actual display of the images on screen display 22. Although graphics card 70 can be of any suitable manufacture, preferably graphics card 70 has at least 8, and more preferably at
25 least 16, Mb of VRAM for optimal performance. An example of a suitable graphics card 70 is the 3Dfx Voodoo Rush™ card. Preferably, the performance of real-time viewer 68 is enhanced by a math optimizer 72, preferably implemented in Visual C++.

 The interaction between segment optimizer 64 and display manager 66 on the one hand, and locator 60 on the other, is provided through a software interface 74,
30 preferably implemented as a Direct Plug-in™ (Microsoft Corp, USA). Software interface 74 enables locator 60 to communicate with the other components of visual

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system 40, in order to provide information regarding the location of the endoscope within the colon.

In preferred embodiments, locator 60 includes a sensor 76, which can be obtained from Ascension Technology Corp., for example. Sensor 76 senses positional information from within a simulated organ 77, which is described herein as a colon for the purposes of discussion and is not meant to be limiting. Sensor 76 is controlled by a control unit 82. The positional information is then relayed to a CPU controller 78, which is connected to a servo-motor 80 (Haydon Switch and Instrument Co.). As the simulated endoscope moves through the colon, the endoscope contacts different portions of the colon. Tactile feedback is provided by each servo-motor 80 in turn, which manipulates the material of the colon.

Visual system 40 also includes a user interface 84, preferably implemented in Visual C++. User interface 84 enables visual system 40 to interact with the preferred feature of a network interface 86, for example, so that other students can view screen display 22 over a network. User interface 84 also permits the tutorial functions of at least one, and preferably a plurality of, tutorial modules 88 to be activated. Tutorial module 88 could include a particular scenario, such as a subject with colon cancer, so that different types of diagnostic and medical challenges could be presented to the student. The student would then need to respond correctly to the presented scenario.

Figures 3A and 3B are schematic block diagrams of an exemplary tool, a simulated biopsy device, for use with the system of Figure 1 or another such system. This biopsy device would simulate the actual biopsy device used to retrieve tissue samples from the gastro-intestinal tract during endoscopy. The actual biopsy device is contained within the endoscope. When the operator of the endoscope wishes to take a sample, the biopsy device emerges from the tip of the endoscope, at which point it is visible on the display screen. The jaws of the biopsy device are then opened and pushed onto the tissue. The jaws are then closed, and the biopsy device retracted. The removal of the tissue causes pools of blood to appear as the remaining tissue bleeds.

Similarly, the simulated biopsy device only appears on the display screen of the system of Figure 1 when the operator of the simulated endoscope causes the simulated biopsy device to emerge. The jaws of the biopsy device are preferably rendered as animation, more preferably in relatively high resolution because the jaws are small, so

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that a high resolution would not prove unduly taxing for the computer. The bleeding of the tissue and the resultant pools of blood are also be animated.

As shown with regard to Figures 3A and 3B, the simulated biopsy device of the present invention features a relatively minimal adaptation of an existing medical tool.

5 These changes enable both tactile force feedback to be provided and the relative location of the simulated device within the simulated colon to be determined, thereby enabling both the physical and visual aspects of the medical procedure to be simulated.

Figure 3A is a schematic block diagram of a simulated biopsy device 100 in a retracted position. As shown, simulated biopsy device 100 features a tool body 102,
10 to which a mobile handle 104 is attached. The human operator moves mobile handle 104 in a lateral direction, such that mobile handle 104 is displaced. The displacement of mobile handle 104 causes a flexible cable 106, to which mobile handle 104 is attached, to be moved. The movement of flexible cable 106 in turn causes the position of a biopsy loop 108 to be displaced in the lateral direction.

15 The lateral displacement of biopsy loop 108 in turn determines whether simulated biopsy device 100 is in the retracted position with regard to a simulated endoscope 110, as shown in Figure 3A, or alternatively extended into simulated endoscope 110, as shown in Figure 3B. When the human operator wishes to position biopsy loop 108 for performing a simulated biopsy procedure, biopsy loop 108 is
20 extended into simulated endoscope 110. Suitable visual and tactile feedback must then be provided for the performance of the simulated biopsy procedure.

Simulated biopsy device 100 preferably provides such force feedback through potentiometry, which is the use of electrical current to generate and adjust physical resistance. Potentiometry has a number of advantages over the use of mechanical
25 components to provide such physical resistance, including the greater ability to adjust the resistance through potentiometry; the reduction in the number of mechanical moving parts which are required; and decreased physical wear on the simulated tool. Thus, potentiometry is particularly preferred for providing tactile, force feedback for the simulated tool of the present invention.

30 As shown in Figure 3B, potentiometric resistance is provided by passing an electrical current through simulated biopsy device 100. The electrical current is supplied through an electrical supply 112, which is connected to flexible cable 106.

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The amount of current is preferably adjusted in order to provide finely tuned physical feedback, by adjusting resistance on simulated biopsy device 100.

Unfortunately, potentiometry has one drawback: it is extremely difficult to provide potentiometric resistance on a flexible, moving object, as potentiometry
5 requires an electrical current to be passed through the object. There is no solution which is known in the background art for this problem

The simulated tool of the present invention solves this problem, as shown in Figure 4, by not directly attaching the entirety of electrical supply 112 to flexible cable 106. Instead, as shown in greater detail with regard to Figure 5A, only a negative
10 electrode 114 is attached to flexible cable 106. Negative electrode 114 is held in place with a first screw 116 and a second screw 118, which hold a clamp 120 against flexible cable 106. The entire assembly is held within a tube 122.

A positive electrode 124 is shown in Figures 4 and 5B. A pin 126 is held in place with a contactor 128. This assembly is held in place with screws 118.
15 Electricity is passed through pin 126 to contactor 128, which does not contact flexible cable 106 directly. Instead, as shown with regard to Figure 5C, electricity is preferably passed indirectly, to a spiral wire 130 which is wrapped around flexible cable 106. Spiral wire 130 is preferably made from a chrome-nickel alloy, and more preferably has a thickness of about 0.08 mm. In comparison, flexible cable 106 preferably has a
20 thickness of about 1.1 mm. The relatively thinness of spiral wire 130 enables positive electrode 124 to be easily added to an existing medical device in order to form the simulated tool of the present invention. Spiral wire 130 is preferably held against flexible cable 106 by tubing 132, which could be Teflon™ for example.

Positive electrode 124, and more particularly contactor 128, is preferably held
25 in place within mobile handle 104 by a spring 134, as shown with regard to Figure 4.

According to a preferred embodiment of the present invention, as shown in Figure 5D, biopsy loop 108 is preferably implemented as a straight cable 136. Straight cable 136 is preferably contained within a guide 138, for attaching simulated biopsy device 100 to the simulated endoscope (not shown). This assembly is preferably
30 further held in place with a spring pad 140, and a clamp 142.

The present invention provides potentiometric resistance on a flexible, moving object, which had not been previously known in the background art. In addition, the

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present invention has the advantage of providing such resistance in a linear manner, such that the amount of resistance is linear over the length of flexible cable 106. The amount of resistance is optionally determined by receiving the analog electrical signal, and converting the signal to digital output. The digital output can then optionally be
5 used with the computer of Figures 1 and 2, for example in order to determine the distance which has been traveled by flexible cable 106.

The linearity of such resistance is important for a number of reasons. First, the distance which flexible cable 106 has traveled is directly proportional to the amount of resistance. The determination of such distance is important for the simulation of the
10 medical procedure, since the provision of suitable visual feedback depends upon determining the location of flexible cable 106 within the simulated endoscope and/or gastro-intestinal tract. Second, the provision of linear resistance enables the amount of resistance to be finely determined in a highly sensitive manner. Thus, the preferred provision of linear resistance is highly useful.

15 Figure 6 is a schematic diagram of a cut-away view of an exemplary but preferred implementation of the force feedback mechanism for the tools according to the present invention. In this implementation, the force feedback is provided through a mechanical device as shown, rather than through the generation of resistance through the application of an electric current. It is understood that some combination of both
20 of these different types of force feedback systems could also optionally be used.

As shown, a simulated endoscope 200 features a tool port 210 for the insertion of a simulated tool 220. Preferably, simulated tool 220 is highly similar in appearance to the corresponding actual medical tool, optionally with the exception of some identifying marking on simulated tool 220 so as to prevent confusion. Simulated tool
25 220 preferably features a cable 230 for insertion into simulated endoscope 200 through tool port 210. The student or other user then operates simulated tool 220 during the simulated medical procedure, for example according to visual feedback received through a video monitor (not shown).

Force feedback is provided on simulated tool 220 through an air-based force
30 generating system 240, which optionally and preferably generates such force against cable 230. Air-based system 240 preferably features an air balloon 250 which presses against cable 230, such that the degree of inflation of air balloon 250 determines the

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amount of force which is applied against cable 230. Air balloon 250 is in turn connected to an air-supply pipe 260 within simulated endoscope 200. Air-supply pipe 260 is then connected to a force-feedback air supply 270. Thus, the degree of inflation of air balloon 250 is determined according to the amount of air supplied by
5 force-feedback air supply 270.

In turn, the activity of force-feedback air supply 270 is more preferably controlled by a computational device 280, which operates an air supply control module 290. Air supply control module 290 preferably calculates the required forces which should be applied to simulated tool 220 through air balloon 250, and then determines
10 the amount of air which should be supplied to air balloon 250 from force-feedback air supply 270.

Generally, these forces may be described as having both an amount and a direction. The forces themselves result from the requirement to simulate events during the simulation; for example, the "collision" of simulated tool 220 with an organ of the
15 body of the subject (not shown). This collision does not need to occur, but any force(s) which would have been generated if the collision had occurred in the body of a living subject do need to be calculated.

In order for the calculation to be accurate, each tool and each organ to be simulated need to be described according to a set of physical specifications, such as
20 size, resiliency, and so forth. For certain activities, such as cutting a portion of an organ for a biopsy, for example, the tissue of the organ would change geometrical shape, which would also affect the forces being generated. Also, the velocity and direction of tool movement need to be considered, in order to create a vector of forces generated by the tool itself. However, as a simplification of these calculations, more
25 preferably, forces generated on the tool, and by the tool, are considered to be linear forces. Such a simplification is still accurate when the actual tool features a long cable which must be inserted into the actual endoscope, as the length of the cable effectively renders the forces only as linear forces.

The procedure for calculating the force involved for the force feedback is
30 preferably performed as follows, with regard to the illustrative, but non-limiting, example of a tool colliding with an organ. The tool has a first velocity before the collision, and a second velocity after the collision. The second velocity is preferably

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calculated according to a simulation model, and more preferably includes physical parameters of the tool and of the organ itself, such as resiliency for example. The force is then computed according to the difference in velocity, times the mass of the tool:

5
$$f = m (v_1 - v_2)$$

in which f is the force to be applied as force feedback; m is the mass of the tool; v_1 is the first velocity (before the collision); and v_2 is the second velocity (after the collision). The air pressure in air balloon 250 is then preferably adjusted, by increasing or decreasing the amount of air in air balloon 250, in order to create the correct
10 amount of force as force feedback.

More preferably, the calculation of the force is expanded to include a plurality of forces which should be generated against simulated tool 220. For example a first force could optionally be the result of a collision between the tool and an organ, while the second force could optionally be the result of cutting a portion of another organ
15 with this same tool. These forces are more preferably all accurately represented in the simulation, and as such should more preferably be accurately applied to simulated tool 220. Therefore, these forces are preferably calculated for a specific tool with all organs in the simulation at any given point in time, and are then summed in order to determine the relative air pressure in air balloon 250, as shown with regard to the
20 following equation:

$$AP \sim \sum F_i$$

in which AP is the air pressure and F_i is the i th force against the tool.

It will be appreciated that the above descriptions are intended only to serve as
25 examples, and that many other embodiments are possible within the spirit and the scope of the present invention.

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WHAT IS CLAIMED:

1. A simulated medical tool for manipulation in a simulated organ by a user, comprising:
 - (a) a tool body;
 - (b) a tool handle attached to said tool body for manipulation by the user;
 - (c) a cable contained in said tool body;
 - (d) a negative electrode attached to said cable; and
 - (e) a positive electrode adjacent to said cable, said positive electrode being in electrical contact with said negative electrode without physically contacting said cable, such that an electrical circuit is formed for providing potentiometric resistance on said cable.
2. The tool of claim 1, wherein a location of said cable within said tool body is adjusted according to manipulation of said tool handle, said tool handle being connected to said cable.
3. The tool of claim 2, wherein said location is determined according to an amount of resistance on said cable.
4. The tool of claim 1, wherein said positive electrode further comprises a wire wrapped around said cable, without physically touching said cable.
5. A system for simulating a medical procedure by a user, the system comprising:
 - (a) a simulated organ;
 - (b) a simulated tool for entering into said simulated organ for performing the simulated medical procedure, said simulated tool comprising:
 - (i) a tool body;
 - (ii) a tool handle attached to said tool body for manipulation by the user;
 - (iii) a cable contained in said tool body;
 - (iv) a negative electrode attached to said cable; and

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- (v) a positive electrode adjacent to said cable, said positive electrode being in electrical contact with said negative electrode without physically contacting said cable, such that an electrical circuit is formed for providing potentiometric resistance on said cable, an amount of said resistance being proportional to a distance traveled by said cable;

and

- (c) a visual display for providing visual feedback according to said distance traveled by said cable in said simulated organ.

6. A simulated medical tool for manipulation in a simulated medical procedure by a user, comprising:

- (a) a tool body;
- (b) a tool handle attached to said tool body for manipulation by the user;
- (c) an air-based force generating system for generating a force against said tool body to provide force feedback to the user, said air-based force generating system generating said force against said tool body according to air pressure to simulate the medical procedure.

7. The tool of claim 6, wherein said air-based force generating system further comprising:

- (i) an air balloon for generating said force against said tool body; and
- (ii) a force-feedback air supply for determining said air pressure in said air balloon.

8. The tool of claim 7, wherein said air pressure in said air balloon is calculated according to an amount of force generated against an actual tool in an actual medical procedure.

9. The tool of claim 7, wherein said tool body further comprises a cable for being contained in said tool body and for contacting said air balloon for said force feedback.

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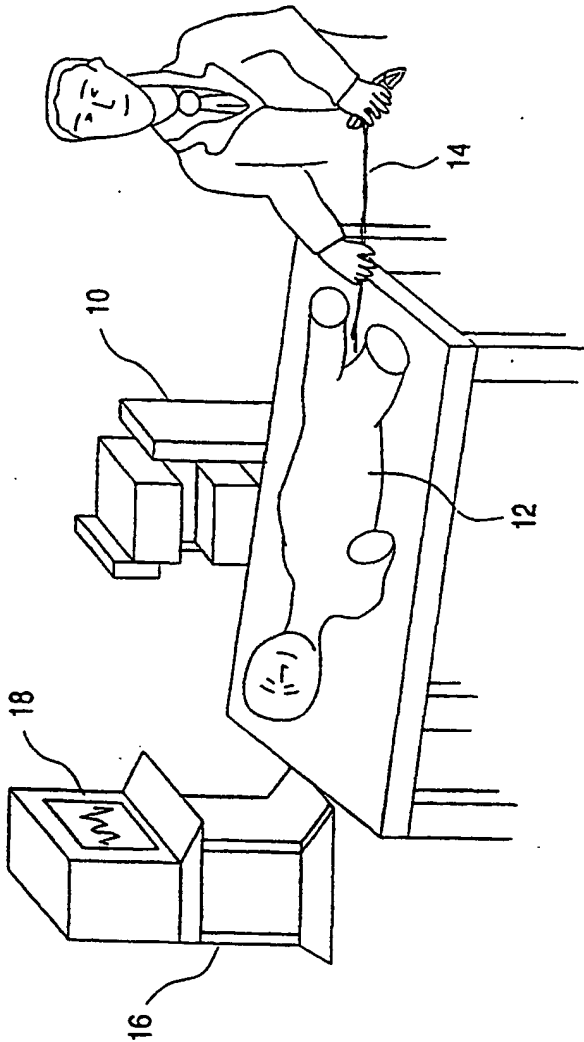


FIGURE 1

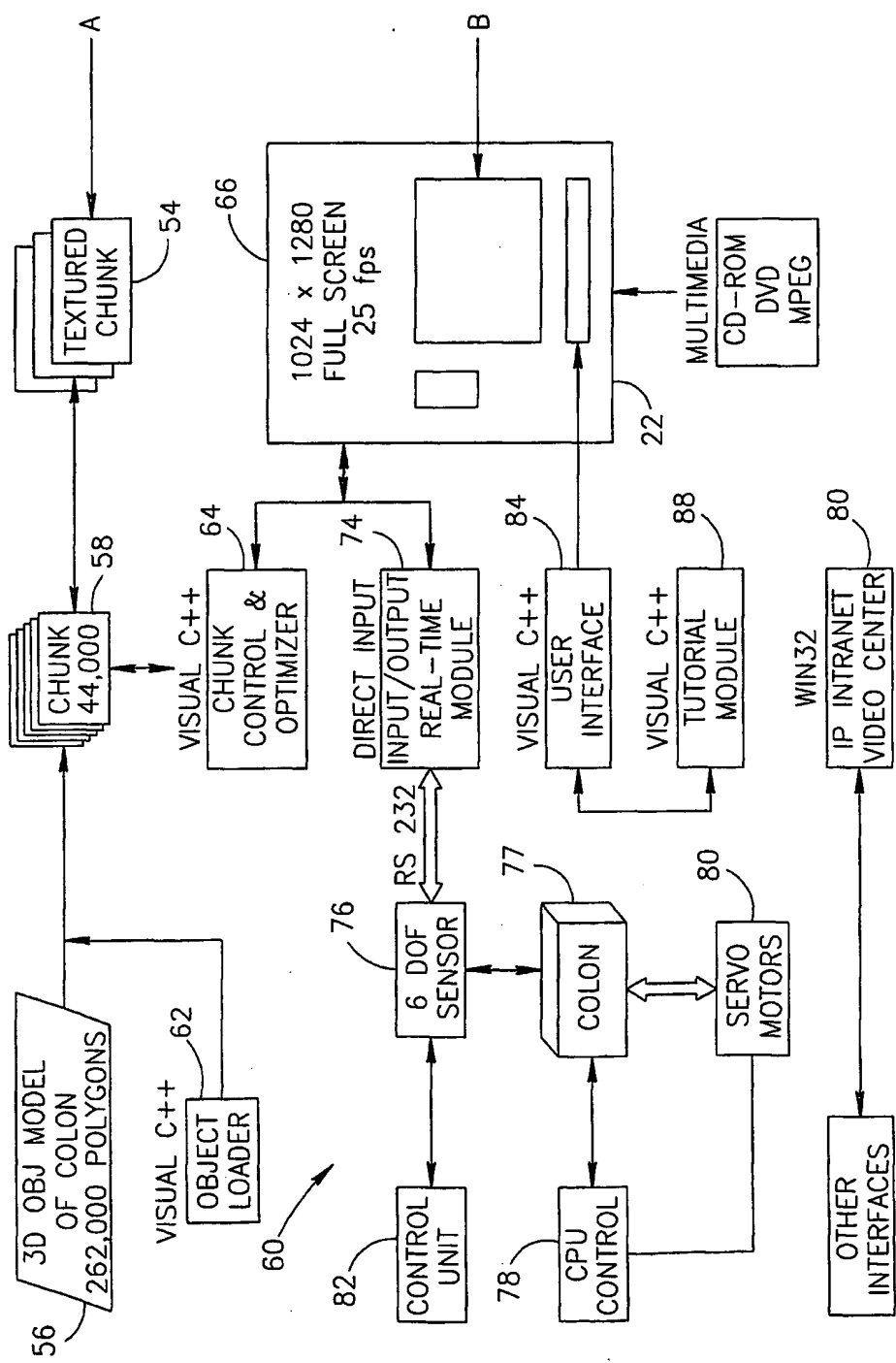
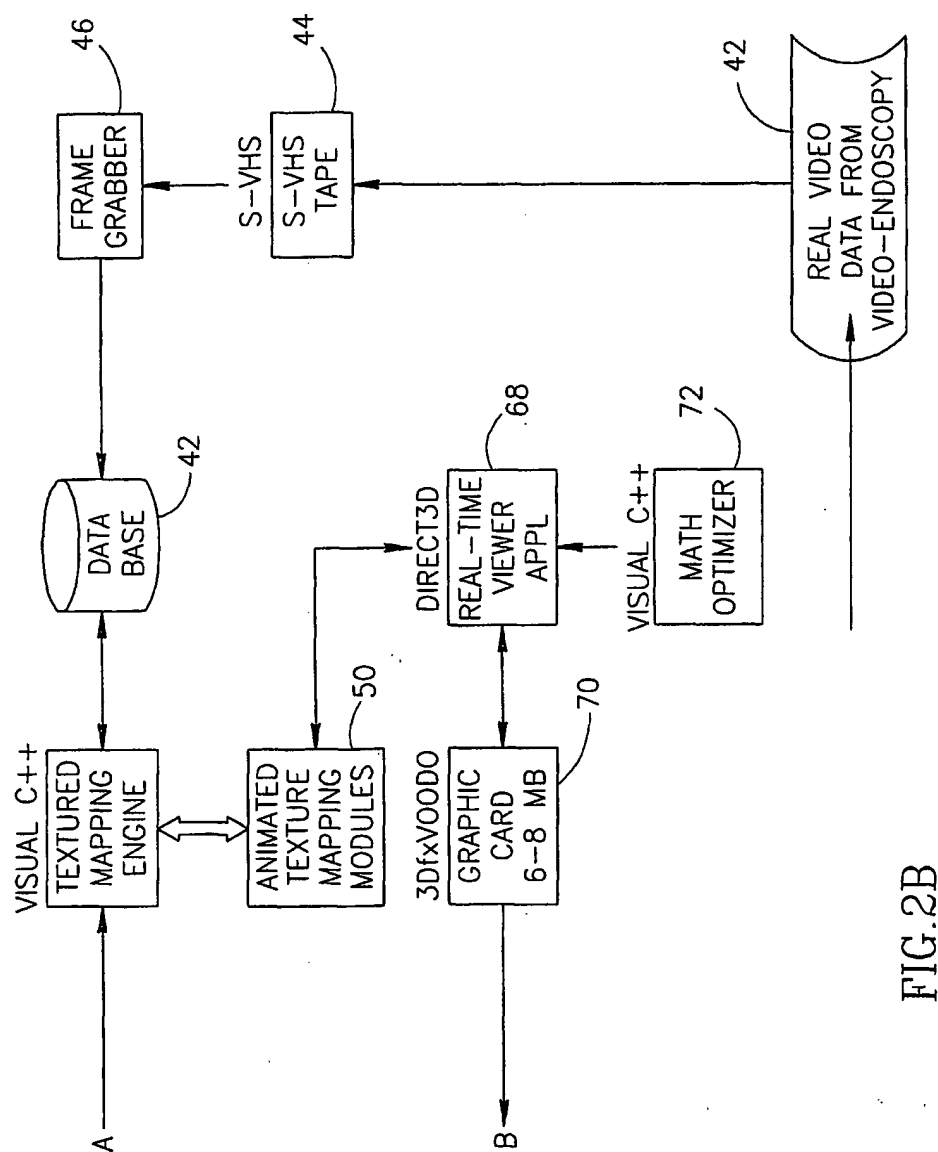


FIG.2A

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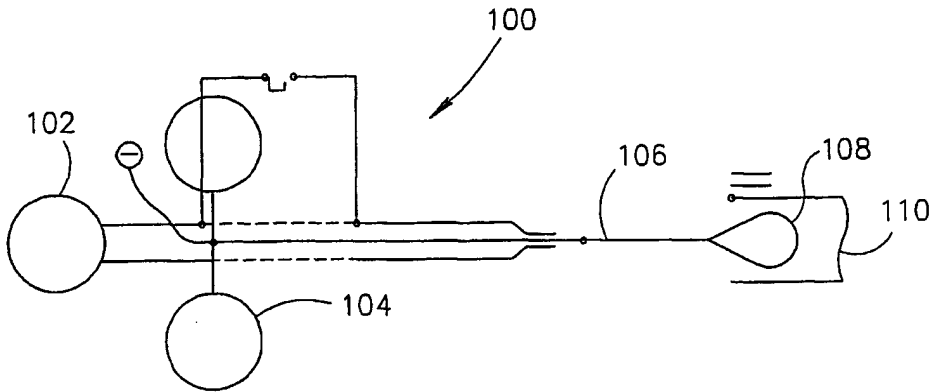


FIG.3A

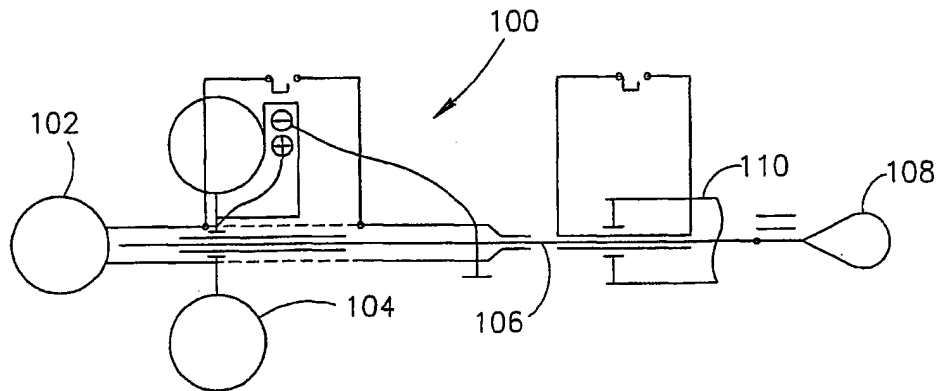


FIG.3B

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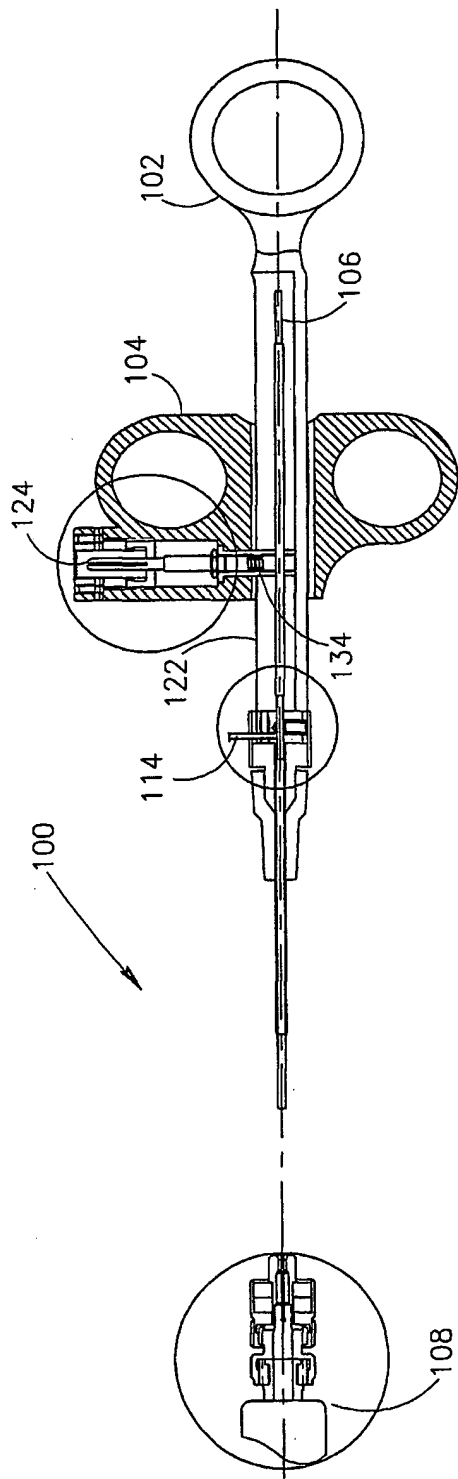


FIG. 4

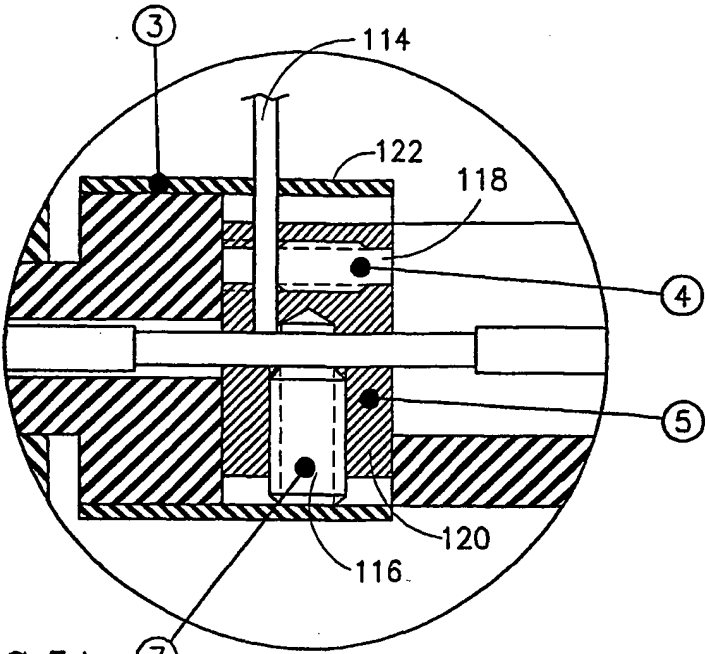


FIG. 5A

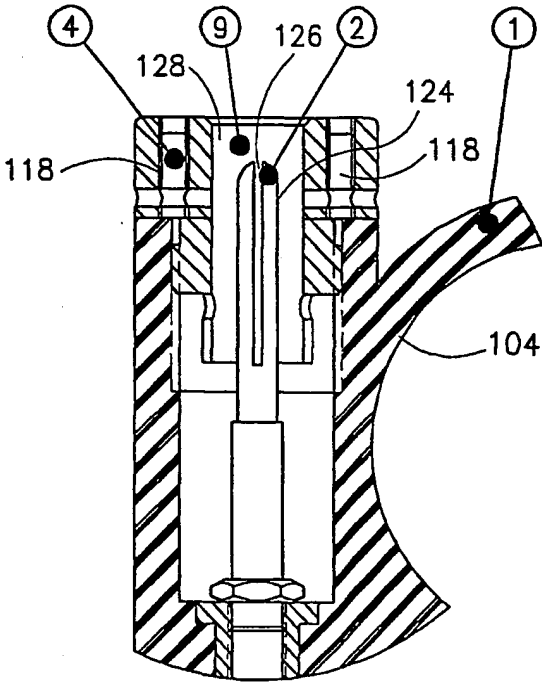


FIG. 5B

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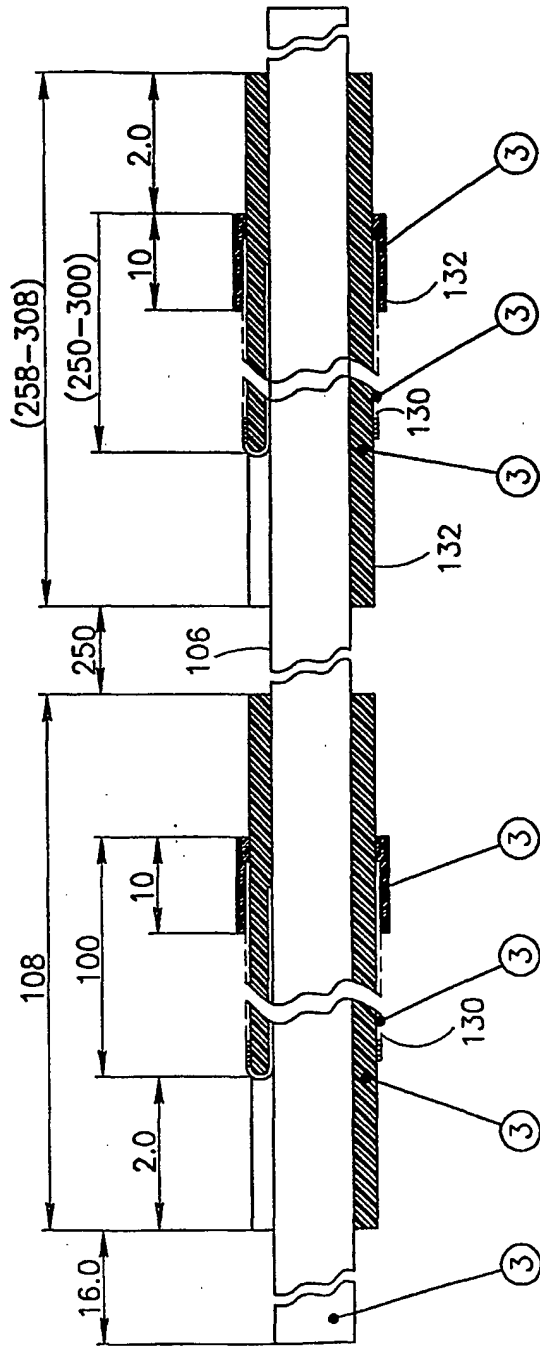


FIG.5C

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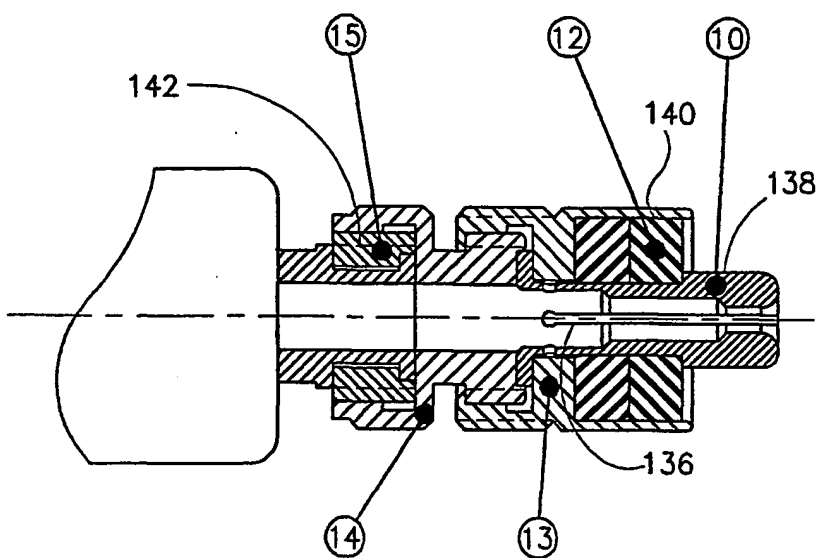


FIG.5D

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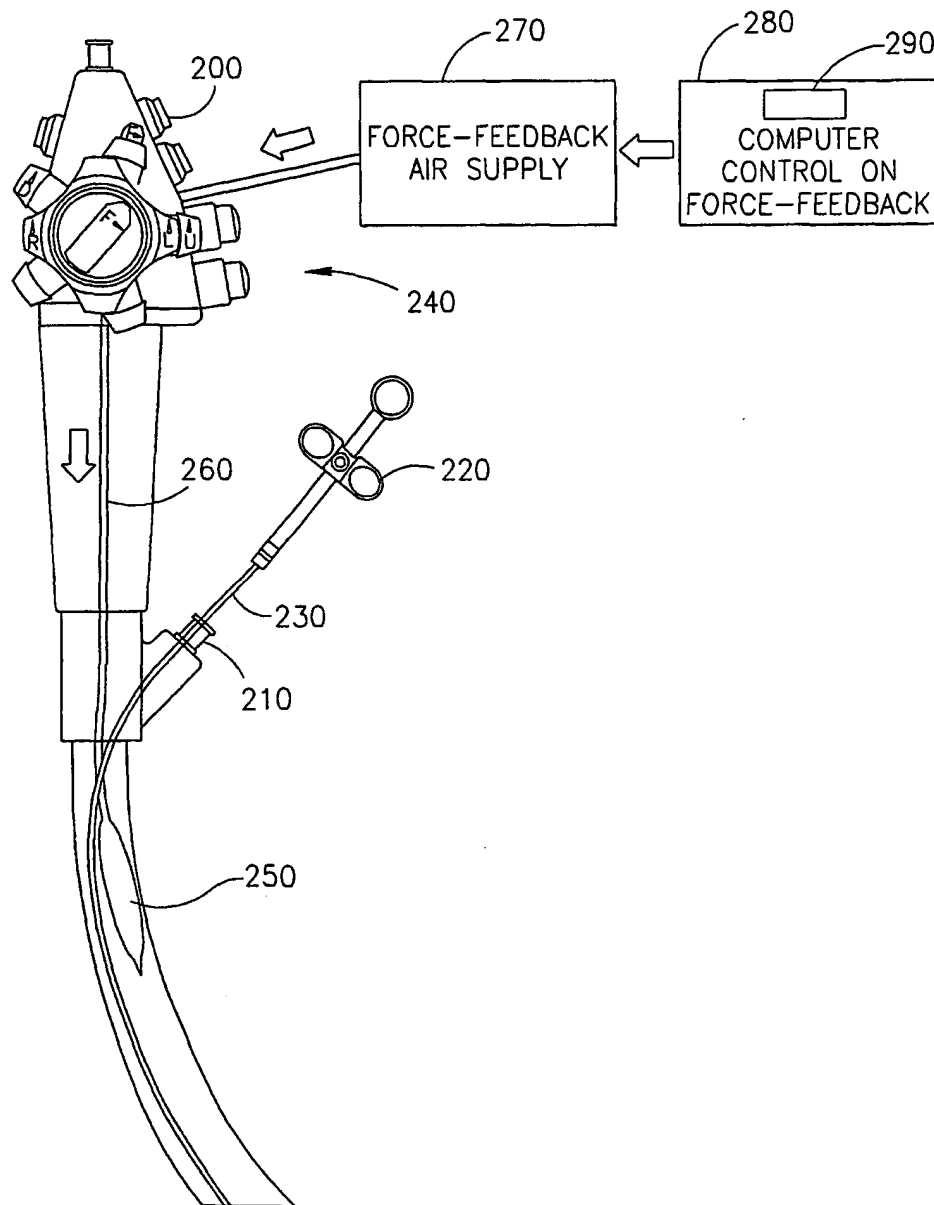


FIG.6

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